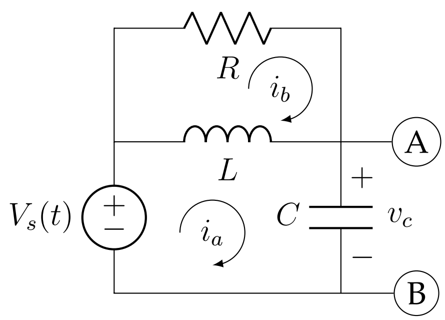
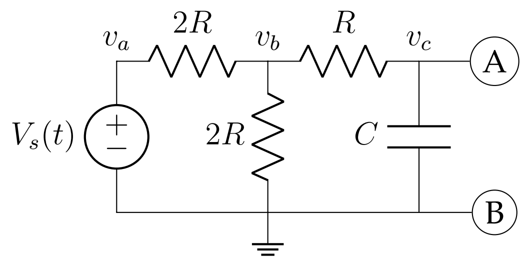
MAE140 – Linear Circuits – Fall – 2019
Final, December 12th

Instructions

1. This exam is open book. You may use whatever written materials you choose, including your class notes and textbook. You may use a handheld calculator with no communication capabilities.
2. You have 170 minutes.
3. Do not forget to write your name and student number.
4. This exam has 6 questions, for a total of 60 points.



(a)



(b)

Figure 1: Circuits for Questions 1-3

1. **Circuit Equivalence - Part I**

   Consider the circuit in Fig. 1a and answer the following questions:

   (a) (1 point) Assume zero initial conditions and convert the circuit into the s-domain.

   (b) (3 points) Calculate the s-domain open-circuit voltage at A and B.

   (c) (3 points) Calculate the s-domain short-circuit current at A and B.

   (d) (2 points) Calculate the equivalent impedance as seen from A and B.

   (e) (1 point) Draw the s-domain Thevenin equivalent for the circuit in Fig. 1a.

2. **Circuit Equivalence - Part II**

   Consider the circuit in Fig. 1b and answer the following questions:

   (a) (1 point) Assume zero initial conditions and convert the circuit into the s-domain.

   (b) (3 points) Calculate the s-domain open-circuit voltage at A and B.

   (c) (3 points) Calculate the s-domain short-circuit current at A and B.

   (d) (2 points) Calculate the equivalent impedance as seen from A and B.

   (e) (1 point) Draw the s-domain Thevenin equivalent for the circuit in Fig. 1b.

3. **Circuit Analysis**

   (a) (4 points) Do not assume zero-initial conditions, convert the circuit in Fig. 1a to the s-domain and formulate its mesh-current equations. Express the component's initial conditions in terms of the indicated mesh-currents and voltage. Use the mesh-currents and labels provided in the figure and clearly indicate the final equations and circuit variable unknowns. Make sure your final equations only involve mesh-currents.

   (b) (5 points) Do not assume zero-initial conditions, convert the circuit in Fig. 1b to the s-domain and formulate its node-voltage equations. Express the component's initial conditions in terms of the indicated node-voltages. Use the node-voltages and labels provided in the figure and clearly indicate the final equations and circuit variable unknowns. Make sure your final equations only involve node-voltages.

   (c) (1 point) Write s-domain expressions for the voltage A and B in terms of the node voltages and mesh currents from parts (a) and (b).

4. **Frequency Response**

   Consider the transfer-function:

$$T(s) = \frac{10s^2}{s^2 + s\,200 + 10{,}000}$$

   and answer the following questions:

   (a) (2 points) What are the poles and zeros of $T(s)$?

   (b) (1 point) Is $T(s)$ asymptotically stable?

   (c) (4 points) Evaluate $|T(j\omega)|$ and $\angle T(j\omega)$ at $\omega = \{0, 100, \infty\}$.

   (d) (2 points) Sketch the functions $|T(j\omega)|$ and $\angle T(j\omega)$ for $\omega \geq 0$.

   (e) (1 point) What type of filter is $T(s)$?

5. (10 points) **OpAmp Design**

   Consider the transfer-function:

$$T(s) = \frac{10s^2}{s^2 + s\,200 + 10{,}000}$$

   from Question 4 and design a circuit using opAmps that implements $T(s)$.

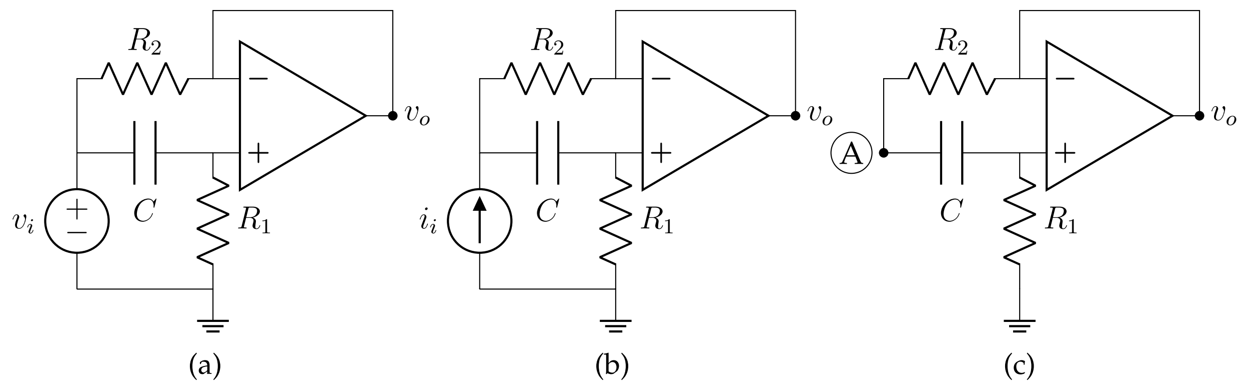


Figure 2: Circuits for Question 6

6. **OpAmp Analysis**

Assume zero initial-conditions for the circuits in Fig. 2 and answer the questions:

(a) (3 points) For the circuit in Fig. 2a show that

$$\frac{V_o(s)}{V_i(s)} = \frac{s}{s + \frac{1}{R_1 C}}.$$

(b) (3 points) For the circuit in Fig. 2b show that

$$\frac{V_o(s)}{I_i(s)} = \frac{sR_1}{s + \frac{1}{R_2 C}}.$$

(c) (2 points) Show that the impedance at point A in Fig. 2c is

$$Z(s) = R_1 \frac{s + \frac{1}{R_1 C}}{s + \frac{1}{R_2 C}}.$$

(d) (1 point) Show that

$$Z(j\omega) \approx R_2 + R_1 R_2 C j\omega$$

when $\omega \ll \frac{1}{R_2 C}$.

Hint: What is the value of

$$\frac{\frac{1}{R_2 C}}{j\omega + \frac{1}{R_2 C}}$$

when $\omega \ll \frac{1}{R_2 C}$*?*

(e) (1 point) Explain why the above circuit is called a "simulated inductor."

Have a great Winter break!